Risk Source Analysis and Grade Division of Subway Tunnel
Undercrossing the Existing Highway Subjected to
the Complicated Geological Environment

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**Keywords:** risk source; grade division; subway tunnel; undercrossing engineering; complicated geological environment.

**Abstract.** According to the characteristics of the subway tunnel method construction and the special operation requirements of the highway, many risks of undercrossing engineering should be required urgent attention. So, based on one subway tunnel undercrossing the existing highway, the possible sources of risk are defined and analyzed. Furthermore, according to the evaluation method of fuzzy mathematics, for soft and hard strata complicated geological environment, the assessment and grading of risk sources are investigated during the subway tunnel undercrossing the existing highway. Those results are supporting the important suggests for constructors and designers.

**Introduction**

With the large-scale construction of urban subway, the tunnel construction has to face the small site, complex geological conditions, all kinds undercrossing the existing structures and non-foreseeable risk factors and other conditions. During the subway construction, engineering accidents are also occur frequently, which is causing huge economic loss and casualties\textsuperscript{[1-3]}. For researches on the new subway tunnel undercrossing existing construction, a lot of risk questions should be studied and resolved, which has no corresponding regulation and relevant norms for designers and constructors\textsuperscript{[4, 5]}. Therefore, at present the results of such projects is to either take too conservative measures, resulting in a great waste, or mining blind or too risky to take countermeasures, a security risk. Many studies have mostly sake of discussion, there is some limitations. So, risk analysis and risk control strategies are becoming a top priority\textsuperscript{[6, 7]}

So, based on one subway tunnel undercrossing the existing highway, the possible sources of risk are defined and analyzed. Furthermore, according to the evaluation method of fuzzy mathematics, for soft and hard strata complicated geological environment, the assessment and grading of risk sources are investigated during the subway tunnel undercrossing the existing highway. Those results are supporting the important suggests for constructors and designers.

**Project Overview**

Shenzhen Metro Line 7 covering the downtown area and two major traffic congestion traffic demand corridors, cohesion Fukuda - Lo passenger distribution point outside the center, when completed, will Luohu, Futian and Nanshan organically combine to ease traffic pressure Huaqiang Area to guide and stimulate the economy, transportation development area to be developed is the southern half of the Shenzhen Special economic zone line ring main living area and employment areas. It is of great significance. Shenzhen Metro Line 7 east to Tai Road, Luohu District, Xili to Lishui Road. Line length of approximately 29.798km. A total of 27 stations across the board, which is located 12 transfer stations. All underground stations, the average station spacing of about 1.048km. Line 7 and Line No. 1,2,3,4,5 Shenzhen Urban Rail Transit has been built, under construction lines 9, 11 and plan
line No. 10,14,15 10 rail crossing Transfer. Among them, the next stop—agriculture, forestry station interval for deep cloud village wear GS 4, as shown in Figure 1 below. Regional and wear this segment is mainly Quaternary Holocene filling artificial soil, gravel (sand) quality clay soil, the underlying bedrock Yanshan granite. Tunnel greater depth, mostly through the formation of a great and strong wind and rock, construction difficult.

![Figure 1. Engineering plan.](image)

**Risk Source Analysis**

For special operations required to wear both the engineering characteristics and highway next subway tunnel under complicated geological conditions, mainly in the following risk sources:

1. Influence of geological engineering and hydrogeology. Regional nature of soil and groundwater conditions tunnels which have a greater impact on surface deformation, the soil in areas with better conditions, the cross section of the excavation face convergence, size and distribution of surface subsidence is relatively easy to control, both during construction of the tunnel have a relatively small impact on the way; and poor geological conditions in the soft soil, due to the low strength of the soft soil layer, the tunnel excavation face self-supporting poor soil, surface subsidence and deformation of the cave by the groundwater flow and water level greater impact change, in order to control the excavation process caused by excessive deformation, generally require the use of special auxiliary construction measures, in order to be able to effectively limit the ground deformation does not exceed the allowable range.

2. Impact of the construction process and technical measures. Tunnel excavation will result in disturbances to the surrounding soil, changing the stress distribution around and hydrogeologic environment, thus causing the surrounding soil deformation, leading to tunnel through the existing road, rail deformation. Due to improper construction methods, pay attention to space-time effects can cause environmental damage (also known as ground loss) is too large to develop into subsidence and collapse phenomenon, which affects both smooth road traffic, may cause serious accidents. At the same time, through the construction process, construction technology and standardized norms at the tunnel site operation is an effective means to reduce the stratum deformation. If the long time interval construction sectors, the lack of timely support surrounding rock excavation or closed, resulting in tunnel face prolonged exposure caused by excessive convergence, ground subsidence caused by
excessive deformation; unreasonable length steps, different steps Construction interfered with each other on the steps at the beginning of the arch support long vacant; premature removal of the temporary support; unqualified support initial injection of concrete quality; unprocessed good construction joints and settlement joints, etc.; these are non-standard construction technology factors affecting ground deformation one will also lead to the formation deformation.

(3) The undercrossing position. Wear positional relationship between the tunnel and the speed of the pavement structure under the influence of the size of the mining law to play a decisive role. The vertical relationship between the tunnel face at the bottom of the highway embankment, on the lower side, according to the principle known highway subgrade force, should roadbed excavation face different vertical positions of great influence pavement structure, and therefore the vertical positional relationship is important; horizontal positional relationship, tunnel excavation disturbed range is limited, the distance from the tunnel face roadbed affected different sizes are different.

(4) Influence of supporting structures. Shallow depth of wear under construction tunnel support in the form of supporting structure and supporting quality directly affects the size of the surface subsidence deformation. Especially the initial support, the structural rigidity of the smaller, less binding on the formation, the greater ground movement, ground subsidence will produce greater. Between initial support and surrounding rock gap is too large, over-excavation backfill grouting section is not timely insufficient, steel frame, bolted between arch grille is not in place, the connection is not snug; lead pipe support system for applying extrapolation angle too large or too small, resulting in partial collapse or pipe roof invasion tunnel clearance will lead to poor support, will greatly reduce the settlement control.

(5) Cross section and size of structures. Under the new tunnel through the existing roadbed may take different forms section, either single holes and single, you can also use a single two-hole, surface subsidence caused by different sections of different sizes. Collect data indicate that, in the same geological and construction conditions, the impact of the tunnel section size of surface subsidence is obvious. Also collected data also show: round, oval structure better able to reduce the impact on the surface.

Risk Grade Division

Fuzzy mathematics evaluation method for soft and lower hard stratum of Subway Tunnel Mine Risk Guangshen Expressway close parallel destruction, carried out the assessment and classification. Risk $r$ is a combination of risk probability $P_r$ and risk events occurring loss of $C_r$.

$$C_r = \sum_{j=1}^{n} o_j C_{ij}$$

For at the same event a risk evaluation, to be made simultaneously on multiple expert assessment of the risk event, and then considering the analysis of the various estimates of experts, to determine the weight of their own experts, according to the formula calculate the risk event.

$$P_r = \sum_{i=1}^{n} (\alpha_i \cdot E_i)$$

So, risk probability level, loss and grade level of risk evaluation are shown in Table 1.

And, the four-color warning center by the risk early warning mechanism, warning the decision, warning issued, consisting of four parts precautions. Warning Center is specifically assume under risk monitoring through professional organizations; Warning Decision refers to the formation of the final warning information through a lot of information and some tools; warning issued is good information distribution network; preventive measures are how to prevent the occurrence of unexpected incidents.
Table 1. Accident probability, scope and weight.

<table>
<thead>
<tr>
<th>Risk Probability</th>
<th>Description</th>
<th>Valuation</th>
<th>Risk Loss</th>
<th>Valuation</th>
<th>Grade Level of Risk Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Happened Frequently</td>
<td>0.9</td>
<td>Catastrophic</td>
<td>0.9</td>
<td>[0.95, 1)</td>
<td>Sky-high</td>
</tr>
<tr>
<td>Happened Possibly</td>
<td>0.7</td>
<td>Very Serious</td>
<td>0.7</td>
<td>[0.8, 0.95)</td>
<td>High</td>
</tr>
<tr>
<td>Happened Once in a while</td>
<td>0.5</td>
<td>Serious</td>
<td>0.5</td>
<td>[0.5, 0.8)</td>
<td>Moderate</td>
</tr>
<tr>
<td>Happened Rarely</td>
<td>0.3</td>
<td>Superior</td>
<td>0.3</td>
<td>[0.0, 0.5)</td>
<td>Minuent</td>
</tr>
<tr>
<td>Impossible</td>
<td>0.1</td>
<td>Slight</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Four-color geological disaster warning level Meaning.

<table>
<thead>
<tr>
<th>Warning Level</th>
<th>Definitions</th>
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<tbody>
<tr>
<td>Red Warning</td>
<td>Special emergency warning for the surrounding rock or surface. Warning Decision determined Settlement reached a high level of risk, a serious collapse of geological disasters occur inside the tunnel, which can lead to sudden disasters and major accidents, with disastrous consequences for tunnel construction.</td>
</tr>
<tr>
<td>Orange Warning</td>
<td>Emergency warning for the surrounding rock or surface. Warning Decision determined Settlement reached the height of the level of risk will occur more serious geological disasters in the tunnel collapsed, the sudden disaster can lead to major accidents, serious impact on tunnel construction.</td>
</tr>
<tr>
<td>Yellow Warning</td>
<td>More urgent warning for the surrounding rock or surface. Warning Decision determined Settlement reached a moderate level of risk, the block may occur out of the tunnel collapse and other geological disasters, will not have a big security incident, but the impact of tunnel construction.</td>
</tr>
<tr>
<td>Blue Warning</td>
<td>General emergency warning for the surrounding rock or surface. Warning Decision determined Settlement reached the low level of risk, large deformation of tunnel surrounding rock occurs or off the block, in strict accordance with NATM, generally does not produce security accident, does not affect the tunnel construction.</td>
</tr>
</tbody>
</table>

Conclusion

In order to investigate the assess the risk and grade level, based on one subway tunnel undercrossing the existing highway, the possible sources of risk are defined and analyzed. Furthermore, according to the evaluation method of fuzzy mathematics, for soft and hard strata complicated geological environment, the assessment and grading of risk sources are investigated during the subway tunnel undercrossing the existing highway. Those results are supporting the important suggests for constructors and designers.

References


